



# Power Electronics

Rajeev Ram, Program Director,  
ARPA-E

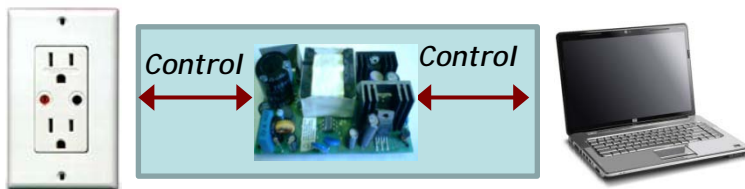
**2010: 30% of all electric power flows through power electronics**  
**2030: 80% of all electric power will flow through power electronics**

# What is Power Electronics?

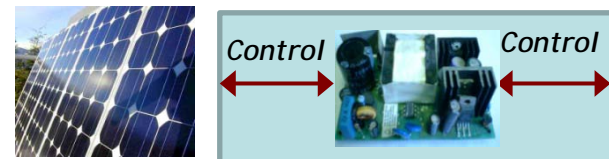
*“The task of power electronics is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited to the load.”*



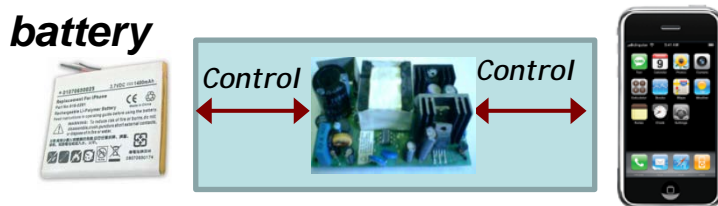
AC/DC Conversion



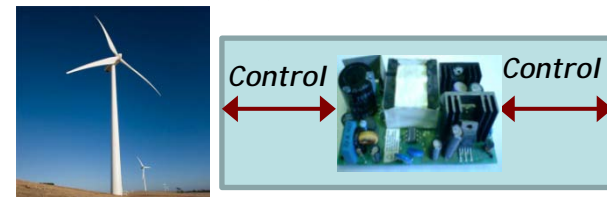
DC/AC Conversion



DC/DC Conversion

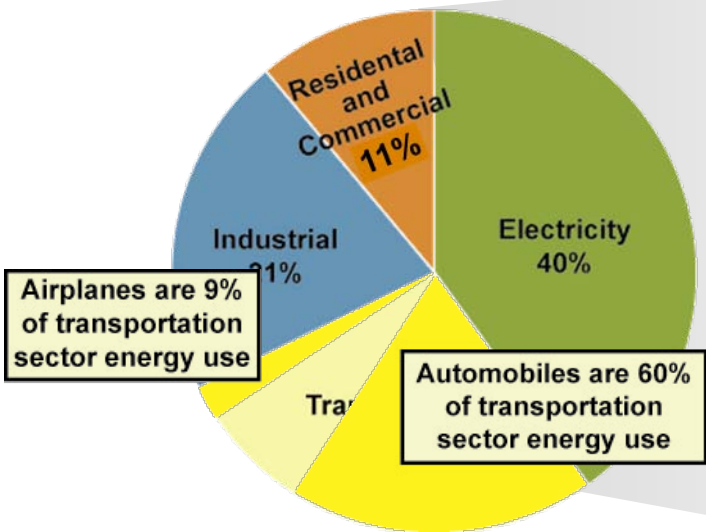


AC/AC Conversion

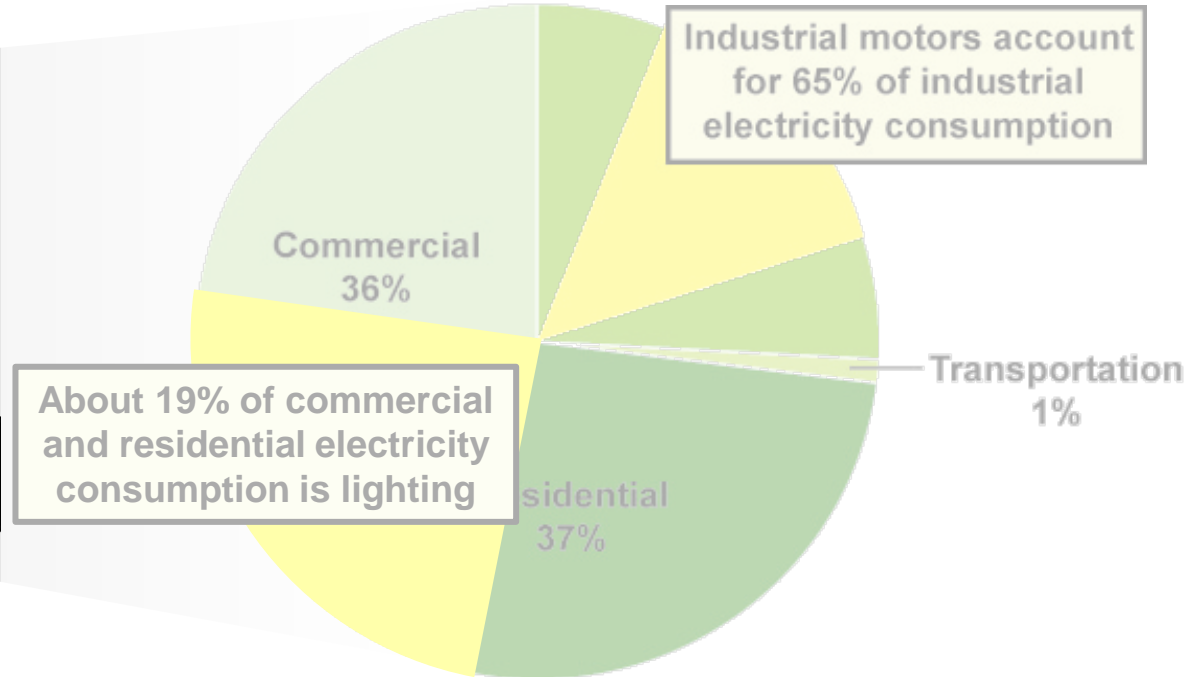


# Agile Delivery of Electrical Power Technology (ADEPT)

Primary Energy Use by Sector



Share of Electricity Consumed by Major Sectors of the Economy, 2008

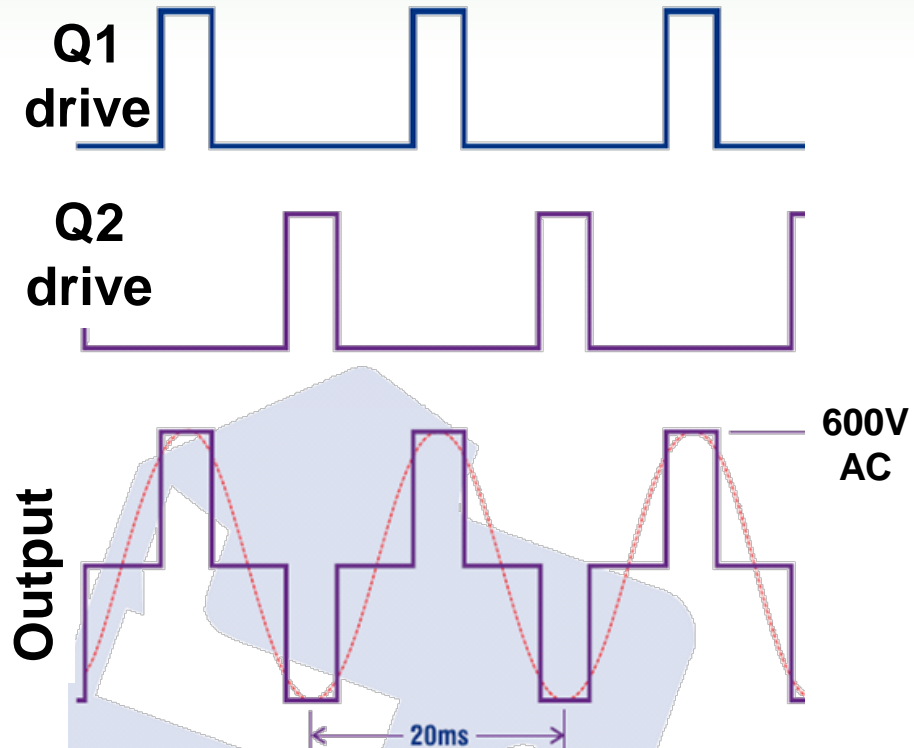
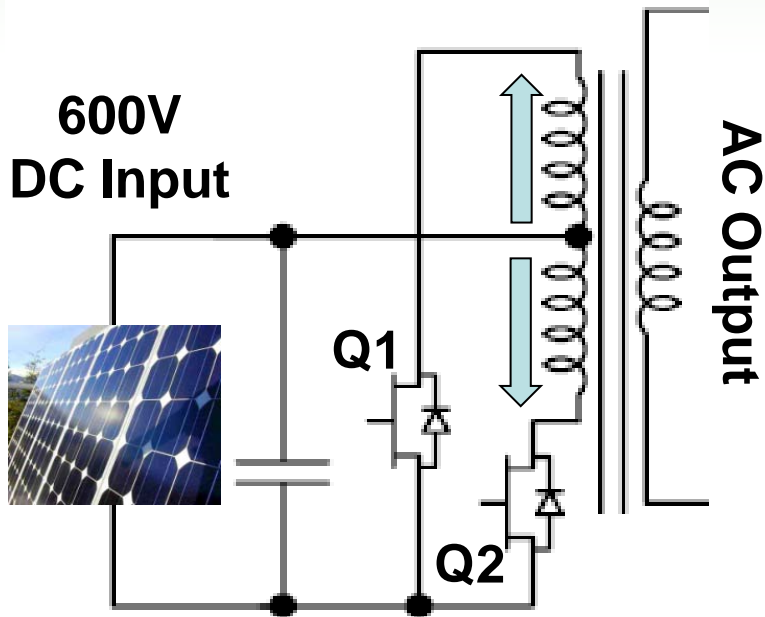


Source: Energy Information Administration, *Annual Energy Review 2008*

- 30-50% of cost for dimmable LED luminaire
- 20% energy loss in industrial motors due to mechanical throttling
- 20% of material cost for HEV is power electronics
- 'No bleed' More Electric Airplanes give 41% reduction in non-thrust power

# One-slide Tutorial

480V  
AC Output



- Switches convert DC to Distorted AC
- Inductors (L) and Capacitors (C) clean AC
- Transformer changes AC voltage level

# Magnetics and Cost

– largest, most expensive part of the converter

>92% Dimmable LED Driver (comm. 37-50% of luminaire cost)

AC/DC Converter



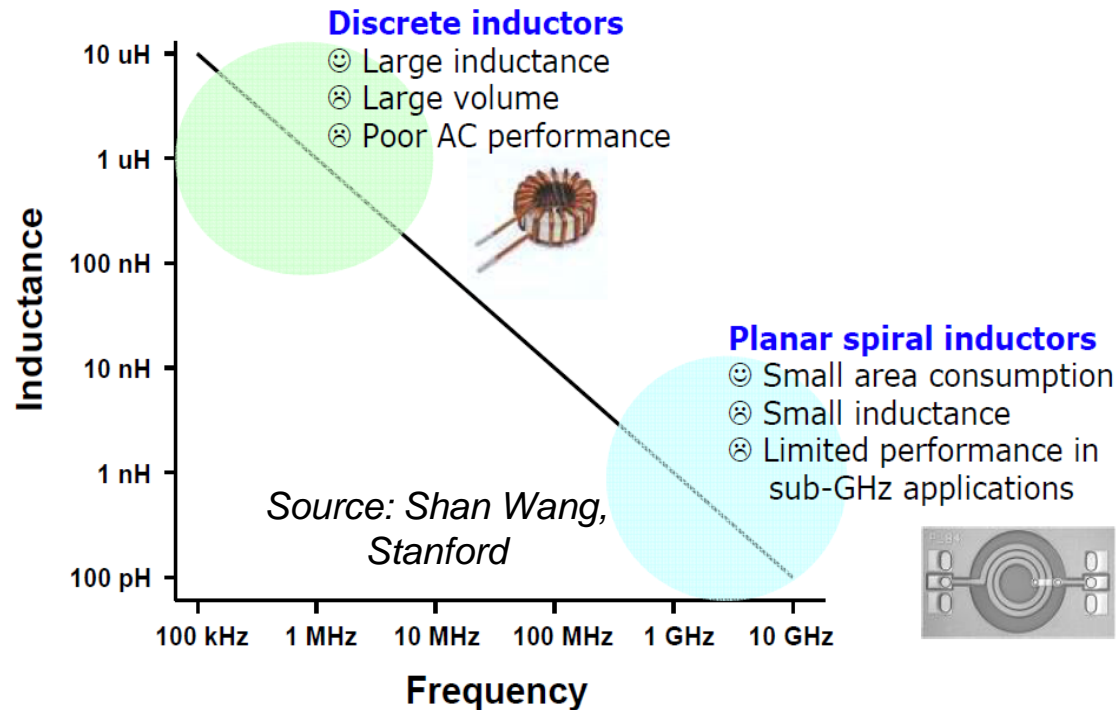
Magnetics

1MW Photovoltaic Inverter  
(\$0.2/W)



40%  
Magnetics

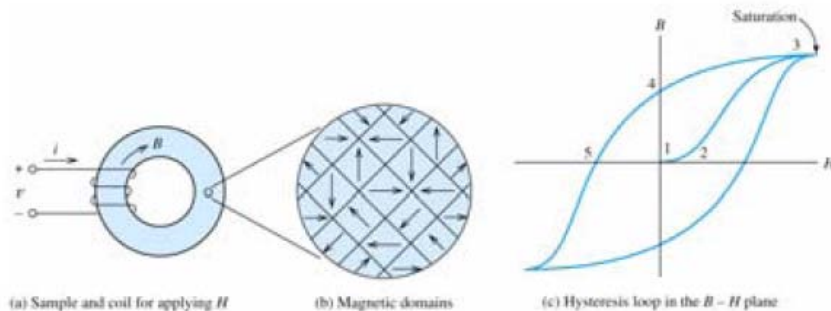
$$Z = j\omega L$$



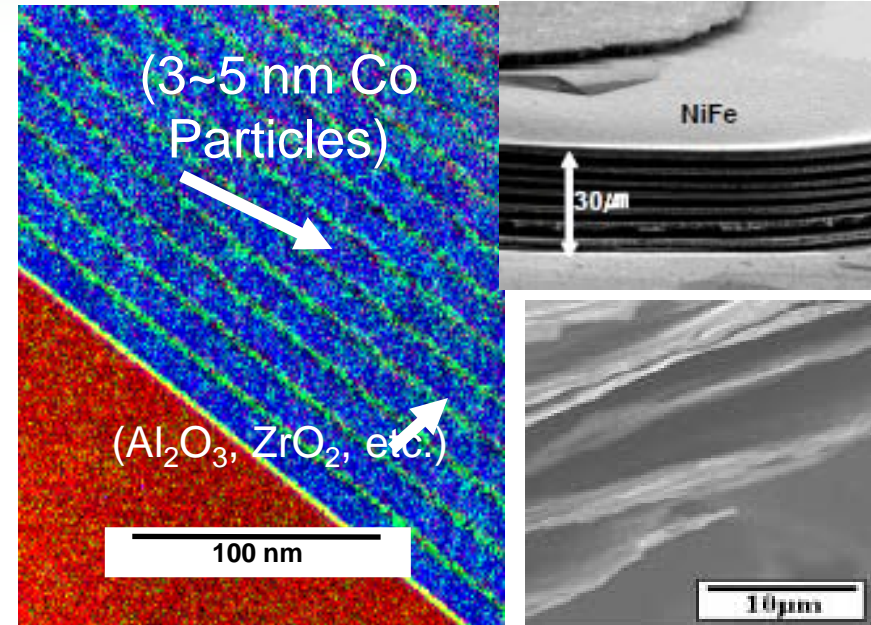
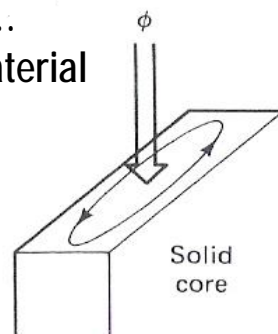
# Limits to Scaling with Frequency & Power

## At hi-frequency, Loss Increases

Energy lost in rotating recalcitrant domains...  
requires soft magnets, low coercive fields



Energy lost induced electrical current...  
requires electrically insulating material  
( $>1 \text{ m}\Omega\cdot\text{cm}$ )



- Ferromagnetic coupled particles or 2D flakes/laminates
- High resistivity ( $300 \sim 600 \mu\Omega\cdot\text{cm}$ ) controls eddy-current loss



# Miniature (Fast) Magnetics Needs Fast Switches

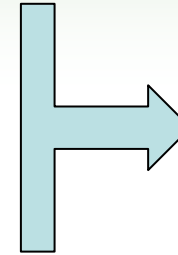
Bandgap (energy to 'free electron') increases



Breakdown voltage increases



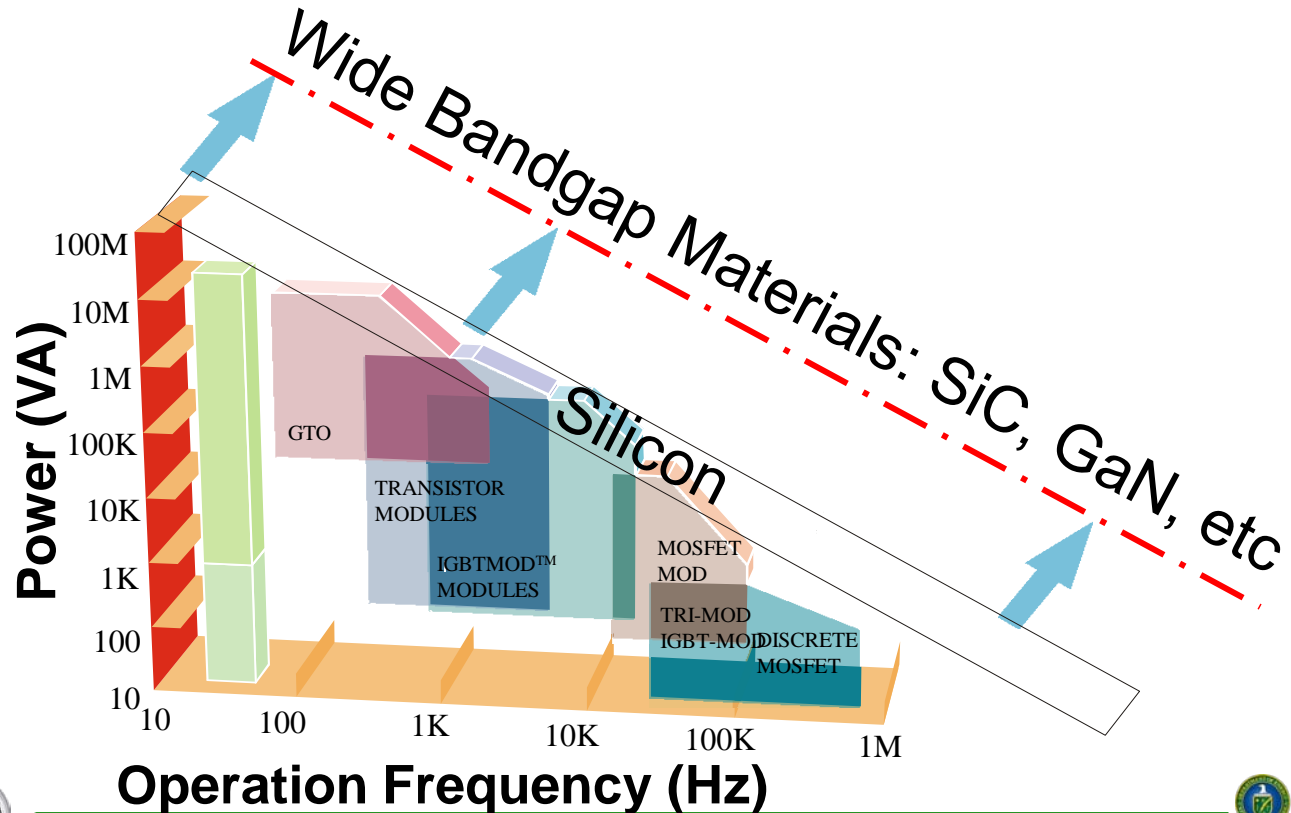
Drift region can be decreased



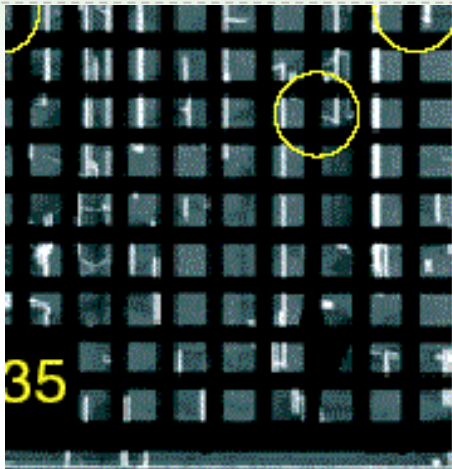
Reduces transit time

Increases frequency

Reduces on-resistance



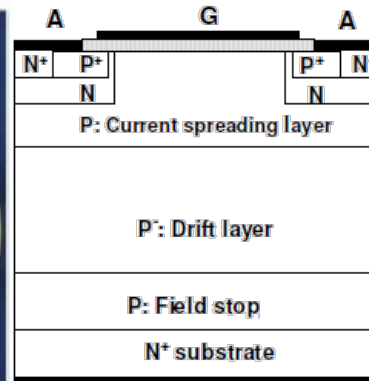
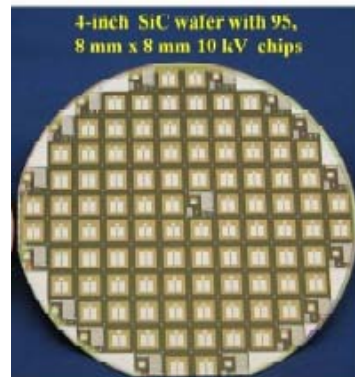
# 20kV & 1MW Transistors



NRL

## ➤ Significantly improved SiC IGBTs

- High voltage (20kV)
- Extremely efficient (>98%)
- Fast switching (50kHz)
- Higher minority carrier lifetimes, and blocking layers – improved reliability and lifetime
- High device yields



	Frequency	Mass	Volume
Today	60 Hz	8,160 lb	4.80m <sup>3</sup>
Tomorrow	50 kHz	100 lb	0.14m <sup>3</sup>

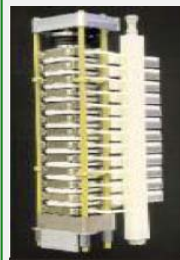


ABB

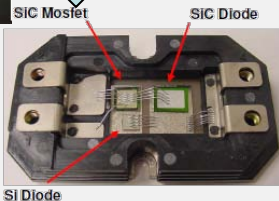


# ARPA-E Supported Power Electronics Innovation

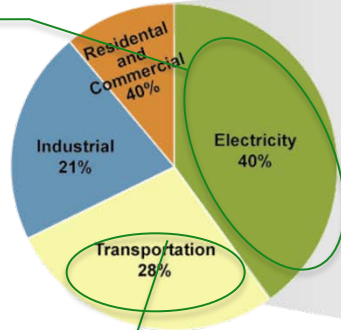
## Distribution & Transmission



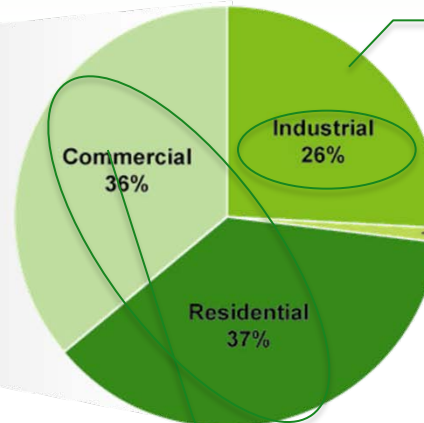
>13 kV,  
50kHz SiC  
transistors



Primary Energy Use by Sector, 2008



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Major Sectors of the Economy, 2008



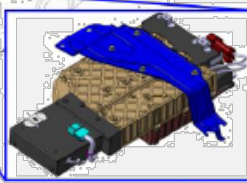
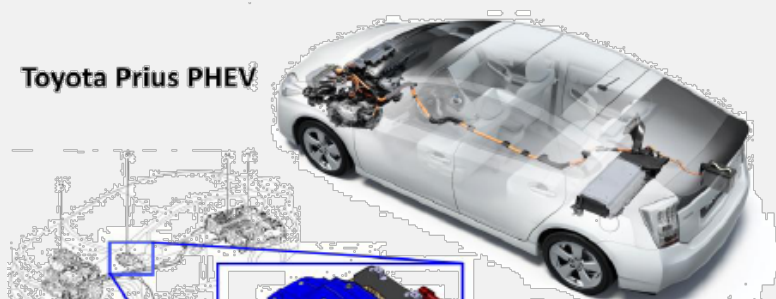
## Industrial

Inverter drives motor



## Automotive

Toyota Prius PHEV



Proposed Next Generation  
SiC High Frequency Charger

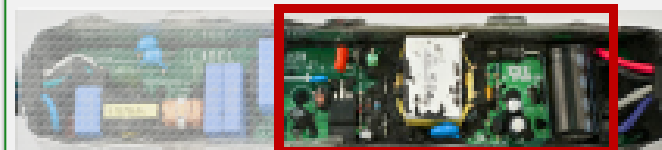
Present  
Plug-In Charger

10x Size/Cost  
Reduction



## Lighting

Existing 25 W AC-DC SSL Driver



EMI Filter

Power Stage:

130 mm x 45 mm x 25 mm

300X reduction in  
power stage volume

